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G4X X6

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None

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VPN, G4X X6
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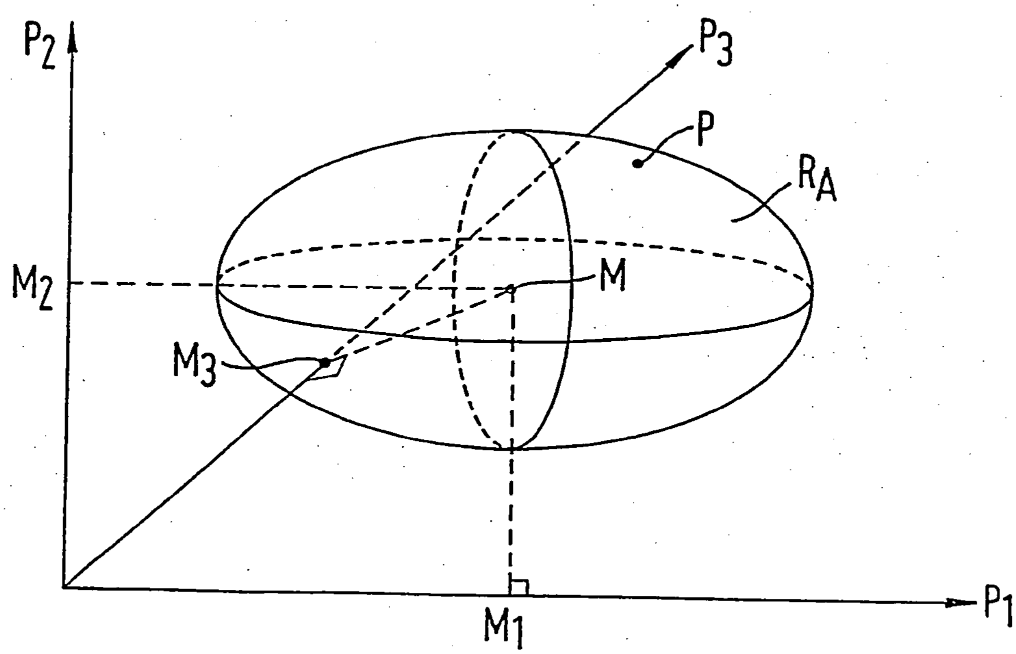
WPI

(54) Validating coins or banknotes

(57) Money items, coins or banknotes, are validated by determining whether a point in n-dimensional space defined by taking n measured properties of an item lie within an n-dimensional ellipse associated with a particular money item. The centre of the ellipse M lies on the statistical mean of the property measurements for that particular item, and each axis P_1, P_2, P_3 is related to the standard deviation for a respective property measurement. A signal may be issued to indicate that the tested item is not genuine if the point lies within the ellipse.

FIG.4.



The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1990.

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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FIG.1.

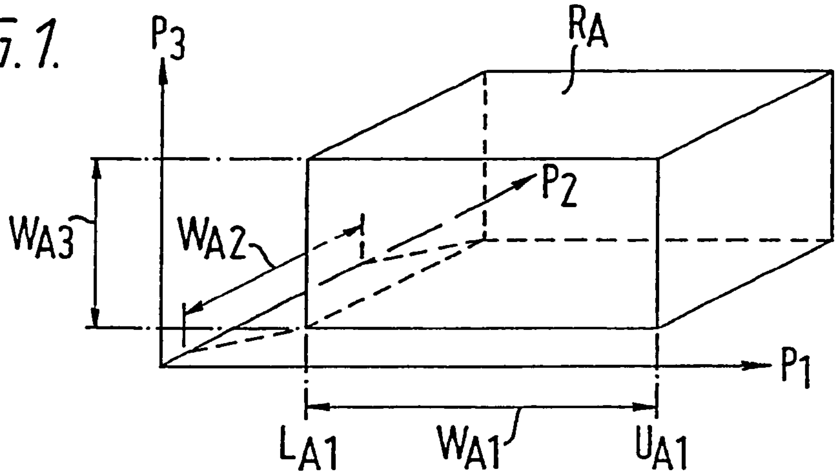


FIG.2.

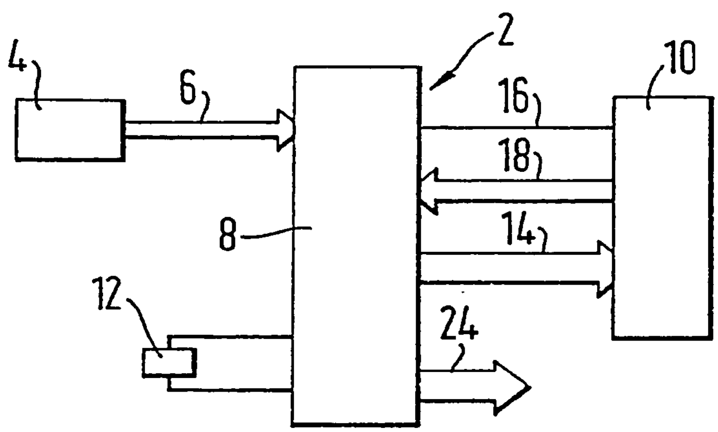


FIG.3.

		A	B	C	D	E	F
P_1		M_{A1}	M_{B1}	M_{C1}	M_{D1}	M_{E1}	M_{F1}
		D_{A1}	D_{B1}	D_{C1}	D_{D1}	D_{E1}	D_{F1}
P_2		M_{A2}	M_{B2}	M_{C2}	M_{D2}	M_{E2}	M_{F2}
		D_{A2}	D_{B2}	D_{C2}	D_{D2}	D_{E2}	D_{F2}
P_3		M_{A3}	M_{B3}	M_{C3}	M_{D3}	M_{E3}	M_{F3}
		D_{A3}	D_{B3}	D_{C3}	D_{D3}	D_{E3}	D_{F3}

FIG.4.

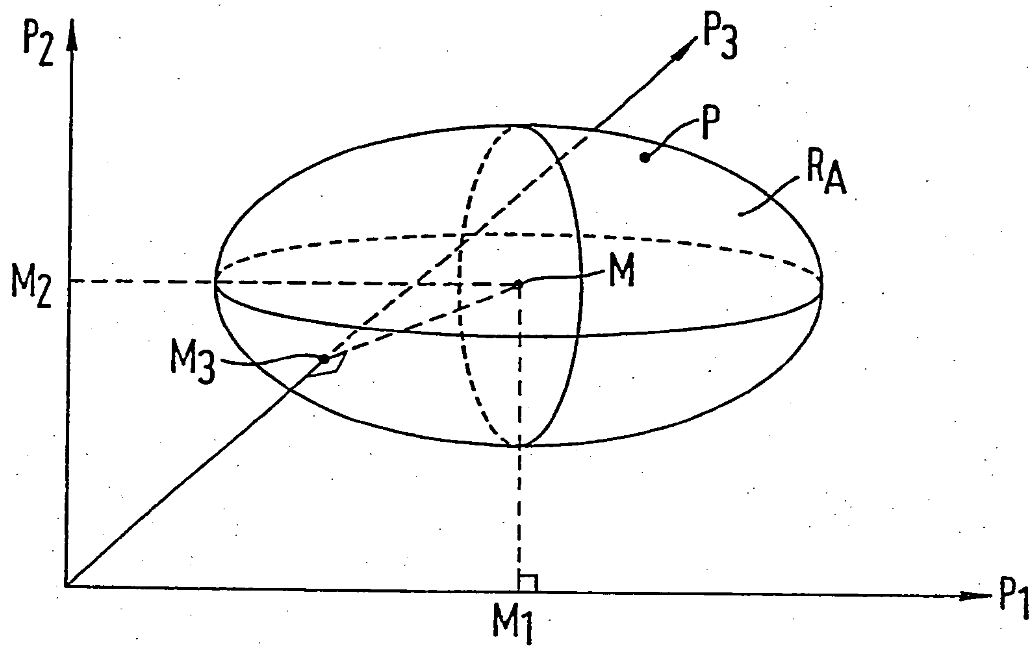
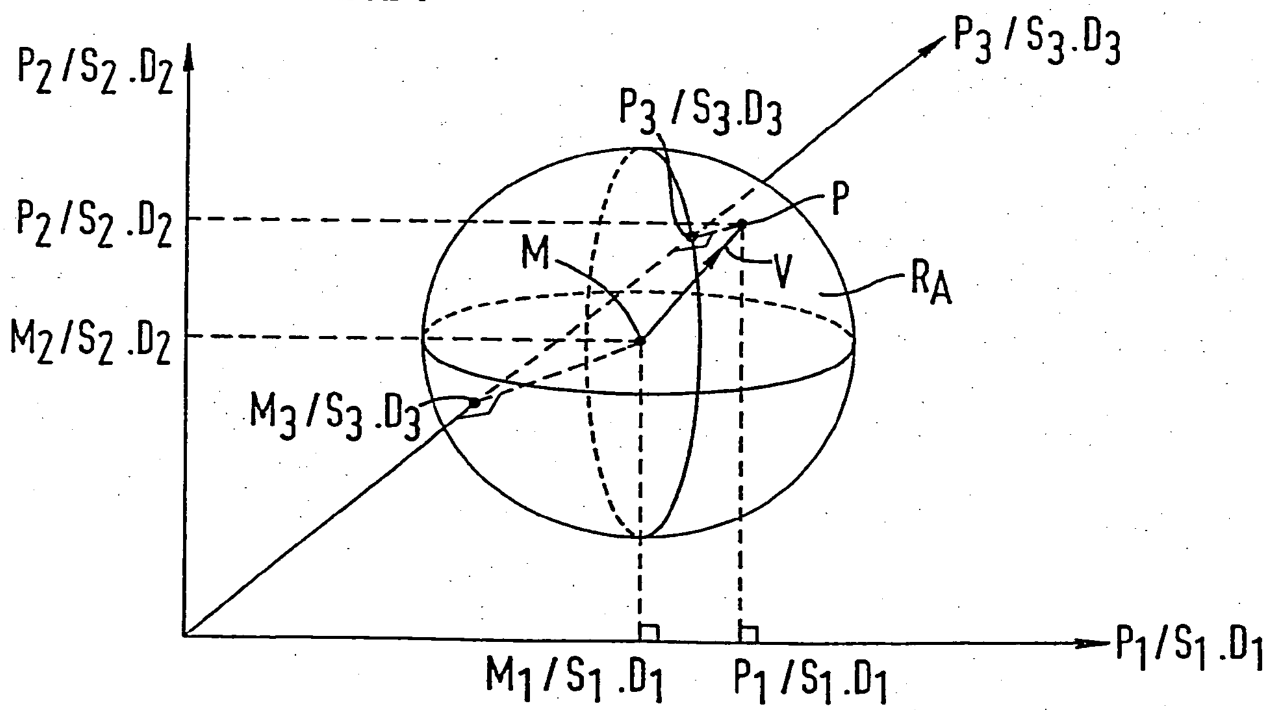

P2
P3
P
RA
M2
M
M3
M1
P1

FIG.5.


P2 / S2 .D2
P3 / S3.D3
P3 / S3.D3
P2 / S2 .D2
P
M
V
RA
M2 / S2 .D2
M3 / S3 .D3
M1 / S1 .D1
P1 / S1.D1
P1 / S1 .D1

METHOD AND APPARATUS FOR VALIDATING MONEY

This invention relates to a method and apparatus for validating items of money, such as coins or banknotes.

It is known when validating coins to perform two or more separate tests on the coin, and to determine that the coin is an authentic coin of a specific type or denomination only if all the test results equal or come close to the results expected for a coin of that type. For example, some known validators have inductive coils which generate electromagnetic fields. By determining the influence of a coin on those fields the circuit is capable of deriving different measurements which are predominantly determined by the thickness, the diameter and the material content of the coins. A coin is deemed authentic only if all three measurements indicate a coin of the same type.

This is represented graphically in Figure 1, in which the three orthogonal axes P_1, P_2 and P_3 represent the three independent measurements. For a coin of type A, the measurement P_1 is expected to fall within a range (or window) W_{A1}, which lies within the upper and lower limits U_{A1} and L_{A1}. Similarly the properties P_2 and P_3 are expected to lie within the ranges W_{A2} and W_{A3}, respectively. If all three measurements lie

within the respective windows, the coin is deemed to be an acceptable coin of type A. In these circumstances, the measurements will lie within an acceptance region indicated at R_A in Figure 1.

In Figure 1, the acceptance region R_A is three dimensional, but of course it may be two dimensional or may have more than three dimensions depending upon the number of independent measurements made on the coin.

Clearly, a coin validator which is arranged to validate more than one type of coin would have different acceptance regions R_B, R_C, etc., for different coin types B, C, etc.

In the prior art, each acceptance window is always predetermined before the test is carried out. Some validators have means for adjusting the acceptance windows. The purpose of the adjustment is either to increase the proportion of valid coins which are determined to be acceptable (by increasing the size of the acceptance window) or to reduce the number of non-genuine coins which are erroneously deemed to be valid (by reducing the size of the acceptance window). Adjustment of the window is carried out either manually, or automatically (e.g. as in EP-A-0155126). In any event, the result of the window adjustment is that the upper and lower limits of the

acceptance window are predetermined.

However, by reducing the acceptance windows in order to avoid accepting non-genuine coins, it is possible that genuine coins will then be found to be invalid. Conversely, by increasing the acceptance windows to ensure that a maximum number of genuine coins are found to be valid, more non-genuine coins may also be determined to be valid. The consequence is that adjustment of windows may have adverse effects as well as beneficial effects, and may not increase the "acceptance ratio" (i.e. the ratio of the percentage of genuine coins accepted to the percentage of non-genuine coins accepted), or may only increase this ratio by a small amount.

In the field of banknote validation, measurements are also compared with acceptance regions generally of the form shown in Figure 1. Similar problems thus arise when modifying the acceptance windows to try to avoid accepting non-genuine notes or rejecting genuine notes.

International Patent Application No. PCT/GB90/01588 and Irish Patent Application No. 3708/90 (the contents of which are incorporated herein by reference thereto) propose a method of validating items of money comprising deriving at least two different measurements of a tested item, determining

whether each measurement lies within a respective range associated with a particular money type, and producing a signal indicating that money of that type has been tested if all measurements fall within the respective ranges for that type, wherein the respective range for at least one of the measurements varies in dependence on at least one other measurement.

The reference to "different measurements" is intended to indicate the measurement of different physical characteristics of the tested item, as distinct from merely taking the same measurement at different times to indicate a single physical characteristic or combination of such characteristics. For example, in GB-A-1 405 937, and in several other prior art arrangements, the time taken for a coin to travel between two points is measured. Although this could be regarded as taking two time measurements and subtracting the difference, the purpose is simply to obtain a single measurement determined by a particular combination of physical characteristics, and therefore this does not represent "different measurements" as this is understood in the present case. Similarly, it is known to take two successive measurements dependent on the position of a coin with respect to a sensor as the coin passes the sensor, and then to take the

difference between those two measurements. Again, this difference would represent a single measurement determined by a single combination of physical characteristics (e.g. a variation in the surface contour of the coin).

In many circumstances, using this technique results in an improved acceptance ratio. For example, it may be found empirically that measurements P_1 and P_2 of valid money items of type A tend to lie within ranges W_{A1} and W_{A2} respectively. However, it may also be found empirically that genuine items having a large value P_1 are unlikely also to have a large value P_2. Using the techniques mentioned above, the upper limit of range W_{A2} can be made smaller when large values of P_1 are detected. This would not significantly affect the number of valid items which are erroneously rejected, but would cause counterfeit items which may have large values of P_1 and P_2 to be rejected.

The present invention is directed to a further and advantageous way of implementing such a technique.

According to the present invention, there is provided a method of validating items of money comprising taking n different measurements of an item of money to define a point in n-dimensional space, determining whether or not the point lies within an n-dimensional ellipse associated with a particular

money item, and using the determination in evaluating whether or not the tested item corresponds to said particular money item. n is an integer equal to or greater than 2.

The invention provides a particularly convenient and effective way of arranging for rejection of money items which exhibit property measurements which in combination suggest that the item is statistically unlikely to be genuine.

Preferably, the centre of the n-dimensional ellipse corresponds to the mean values of the n different measurements for a population of those particular money items, as determined by statistical analysis. These mean values may differ between individual coin testing apparatuses, and if desired, a calibration process can be carried out in order to determine the mean values (or quantities related thereto) for the individual testing apparatuses. Preferably, the size of the n-dimensional ellipse, when measured along each axis corresponding to a respective property measurement, is equal to a predetermined factor multiplied by the standard deviation of the respective property measurement for that particular money item, as determined by statistical analysis. These standard deviations may be assumed to be the same for individual testing

apparatuses of the same general type, i.e. individual calibration may not be required to derive the standard deviation value.

The invention also extends to money validating apparatus arranged to operate in accordance with a method of the invention.

Arrangements embodying the invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 schematically illustrates an acceptance region in a conventional validator;

Figure 2 is a schematic diagram of a coin validator in accordance with the present invention;

Figure 3 illustrates by way of example a table stored in a memory of the validator of Figure 2, the table defining acceptance regions;

Figure 4 schematically illustrates an acceptance region for the validator of Figure 2;

Figure 5 schematically illustrates the Figure 4 acceptance region using different axes.

The coin testing apparatus 2 shown schematically in Figure 2 has a set of coin sensors indicated at 4. Each of these is operable to measure a different property of a coin inserted in the apparatus, in a manner which is in itself well known. Each sensor provides a signal indicating the measured value of the

respective parameter on one of a set of output lines indicated at 6.

An LSI 8 receives these signals. The LSI 8 contains a read-only memory storing an operating program which controls the way in which the apparatus operates. Instead of an LSI, a standard microprocessor may be used. The LSI is operable to process the measured values received on respective input lines 6 with data values stored in predetermined locations in a PROM 10. The PROM 10 could be any other type of memory circuit, and could be formed of a single or several integrated circuits, or may be combined with the LSI 8 (or microprocessor) into a single integrated circuit.

The LSI 8, which operates in response to timing signals produced by a clock 12, is operable to address the PROM 10 by supplying address signals on an address bus 14. The LSI also provides a "PROM-enable" signal on line 16 to enable the PROM.

In response to the addressing operation, a data value is delivered from the PROM 10 to the LSI 8 via a data bus 18.

By way of example, one embodiment of the invention may comprise three sensors, for respectively measuring the conductivity, thickness and diameter of inserted coins. Each sensor comprises one or more

coils in a self-oscillating circuit. In the case of the diameter and thickness sensors, a change in the inductance of each coil caused by the proximity of an inserted coin causes the frequency of the oscillator to alter, whereby a digital representation of the respective property of the coin can be derived. In the case of the conductivity sensor, a change in the Q of the coil caused by the proximity of an inserted coin causes the voltage across the coil to alter, whereby a digital output representative of conductivity of the coin may be derived. Although the structure, positioning and orientation of each coil, and the frequency of the voltage applied thereto, are so arranged that the coil provides an output predominantly dependent upon a particular one of the properties of conductivity, diameter and thickness, it will be appreciated that each measurement will be affected to some extent by other coin properties.

The apparatus so far described corresponds to that disclosed in GB-A-2094008. In that apparatus, on insertion of a coin, the measurements produced by the three sensors 4 are compared with reference values stored in a region of the PROM 10. Each property measurement is compared with the upper and lower limits, representing a window, for each of six coins A to F. If the measured properties all lie within the

upper and lower limits of the respective ranges for a particular coin, then the coin is deemed valid and the LSI 8 produces an ACCEPT signal on one of a group of output lines 24, and a further signal on another of the output lines 24 to indicate the denomination of the coin being tested. The validator has an accept gate (not shown) which adopts one of two different states depending upon whether the ACCEPT signal is generated, so that all tested coins deemed genuine are directed along an accept path and all other tested items along another path.

The validator of GB-A-2094008 has acceptance regions, defined by the values stored in PROM 10, generally of the form shown in Figure 1.

In the present embodiment of the invention, however, each of the six acceptance regions has the form shown at R_A in Figure 4. This differs from the region of Figure 1 in that it is substantially ellipsoidal in shape. The width of the region R_A, when measured along the axis P_1, is preferably equal to $s.D_1$, where D_1 represents the standard deviation of the measured property P_1 of a population of coins from the mean value (which has been empirically determined prior to calibration of the validator), and s represents a predetermined acceptance factor which is calculated in accordance with the desired statistical

likelihood of a coin which is accepted by the validator actually being genuine. The factor s is determined in accordance with the desired compromise between accepting non-genuine items and rejecting genuine items. Similarly, the region R_A has widths when measured in the directions of axes P_2 and P_3 which are equal to $s.D_2$ and $s.D_3$, respectively. (If desired, the factor s may vary for one or more of the axes.)

It will be appreciated that items falling within the region R_A are statistically likely to be acceptable coins, whereas items falling outside the acceptance region, i.e. items which have more than one property which exhibit values close to the individual limits for the respective properties, are statistically unlikely to be genuine.

The mid-point M of the region R_A in Figure 4 is the statistical mean of the coin population measurements for each of the properties P_1, P_2 and P_3.

One possible way of operating the validator in order to achieve an acceptance region R_A as shown in Figure 4 will be explained below.

With reference to Figure 3, the PROM 10 stores, for each of coin denominations A to F, a value (e.g. M_{A1}) representing the statistical mean of the measurements of property P_1 of a population of coins of denomination A, and a value (e.g. D_{A1}) representing the

standard deviation for those property measurements, and corresponding values for the other properties P_2 and P_3.

In order to validate an inserted item, the LSI takes all three of the measurements P_1, P_2 and P_3 of the inserted item. The LSI then addresses the PROM 10 so as to read out therefrom the stored values relating to coin A, in order for the LSI to be able to perform the following calculation:

$$Dist=\left(\frac{P_1 - M_1}{D_1}\right)^2 + \left(\frac{P_2 - M_2}{D_2}\right)^2 + \left(\frac{P_3 - M_3}{D_3}\right)^2 \qquad \ldots (1)$$

The value Dist corresponds to the length of a vector from the mid-point M of the acceptance region to the point representing the measured properties P_1, P_2 and P_3. The LSI then tests to determine whether Dist $\geq$ K, where K is a predetermined value. If this test is passed then the measured properties lie outside the acceptance region R_A, and the item is deemed to be non-genuine. Otherwise, the test for the property measurements P_1, P_2 and P_3 have been passed.

The above calculation assumes s to be the same for all properties. If s differs, the test can be modified to:

$$\left(\frac{P_1 - M_1}{s_1 . D_1}\right)^2 + \left(\frac{P_2 - M_2}{s_2 . D_2}\right)^2 + \left(\frac{P_3 - M_3}{s_3 . D_3}\right)^2 \geq K' \qquad \ldots (2)$$

(where K' is a predetermined constant) and the PROM 10 can store the products $s_1.D_{A1}$, $s_2.D_{A2}$, ... etc. instead of the deviations D_{A1}, D_{A2}, ... etc.

The value Dist effectively represents a single distance value signifying how close all the property measurements are to the statistical mean. This can be seen more clearly by referring to Figure 5, which replots the acceptance region R_A of Figure 4 on to axes which represent the ratios of the properties P_1, P_2 and P_3 to the products of the respective acceptance factors and standard deviations $s_1.D_1$, $s_2.D_2$ and $s_3.D_3$, and thus have corresponding scales. It will be seen that the acceptance region R_A becomes spherical. The value Dist represents the length of the vector V from the mid-point M to the point P representing the measured properties. To reduce the amount of calculation needed, the valued Dist is actually equal to the square of this distance, but this does not matter so long as the constant K is chosen appropriately.

Once the evaluation has been carried out in respect of coin A, the same process is carried out in respect of the other coins B to F, which would have respective acceptance regions at different locations and probably of different sizes.

If desired, the calculation could be modified. In general, the following formula could be evaluated to determine whether a coin is acceptable:

$$\sum_{1}^{n} (a_n P_n - b_n)^2 \geq K'' \qquad \ldots (3)$$

wherein K" is a predetermined constant, and a_n, b_n are coefficients for each of the n properties of a particular coin denomination, which can be derived using statistical techniques on a population of coins of that denomination. These coefficients could be individually calculated and separately stored, or as in equations (1) and (2) other coefficients related thereto could be stored.

Although it is preferred that this technique be used to test for all the denominations of the coin set with which the validator is to be used, the technique could instead be applied just to the testing of one or more of the coin denominations. It may also be used only in respect of some of the measured properties, further properties being used to evaluate acceptance in a conventional manner.

Although the technique has been described in respect of acceptance regions, whereby a coin is deemed to be valid if its properties lie within the region, the technique is also applicable to rejection regions, i.e. regions within which the properties of specific types of non-genuine items are expected to lie. Thus, if the measured properties are found to lie within such a rejection region, the item is deemed

to be non-genuine and rejected.

It is possible to have overlapping regions each associated with a respective different item, in which case the region within which the measured properties are deemed to lie is that associated with the closest mid-point to the measured properties.

As an alternative procedure, irrespective of whether or not there are overlapping regions, the LSI 8 may perform a pre-classifying step whereby it determines which mid-point is closest to the measurement point, thus nominally identifying the tested item, and then determine whether or not the measurement point lies within the ellipse surrounding the mid-point, thus determining acceptability.

The measurements of the properties, as represented in Fig. 4, could be values proportional to physical quantities, but they need not be. They could for example be values representing changes in a physical parameter, such as the frequency of an oscillator, caused when an item moves to a testing position.

References herein to coins are intended to encompass also tokens and other coin-like items.

Although the preceding description relates to the field of coin validation, it will be understood that the techniques are similarly applicable to banknote validation.

CLAIMS:

1. A method of validating items of money, the method comprising taking n different measurements of an item of money (where n is an integer equal to or greater than 2) to define a point in n-dimensional space, determining whether or not the point lies within an n-dimensional ellipse associated with a particular item, and using the determination in evaluating whether or not the tested item corresponds to said particular item.

2. A method as claimed in claim 1, the method including the step of determining whether or not the point lies within any one of a plurality of n-dimensional ellipses each associated with a respective type of money item, and providing a signal indicative of the type of item which has been tested in accordance with the ellipse within which the point has been found to lie.

3. A method as claimed in claim 1, wherein the ellipse is associated with a non-genuine item, and the method includes the step of issuing a signal indicating that the tested item is not genuine if the point lies within said ellipse.

4. A method of validating items of money comprising taking n different measurements of an item of money (wherein n is an integer equal to or greater than 2) and determining whether the following expression when evaluated is equal to or greater than a predetermined constant:

$$\sum_{1}^{n} (a_n P_n - b_n)^2 ,$$

wherein $P_1 \ldots P_n$ are related to the respective n measurements and $a_1 \ldots a_n$, $b_1 \ldots b_n$ are predetermined coefficients.

5. A method as claimed in claim 5, wherein each of the coefficients $a_1 \ldots a_n$, $b_1 \ldots b_n$ is individually stored to enable its use for evaluating said expression.

6. A method as claimed in claim 5, wherein other coefficients related to the coefficients $a_1 \ldots a_n$, $b_1 \ldots b_n$ are stored to enable their use in the evaluation of said expression.

7. A method validating items of money, the method being substantially as herein described with reference to the accompanying drawings.

8. A method of setting up a money validator to enable it to validate items of a particular type, the method comprising determining the statistical mean for each of n different measurements of items of said particular type to be made by the validator (where n is an integer equal to or greater than 2), defining an n-dimensional ellipse having a center which corresponds with said statistical mean, and storing information defining said ellipse in the validator to enable the validator to determine whether or not measurements made on a tested item define a point within the ellipse, and thereby determine whether or not the tested item is of said particular type.

9. A method as claimed in claim 8, wherein the method involves determining the statistical mean of each measurement individually for each of a plurality of coin validators.

10. A method as claimed in claim 8 or claim 9, wherein each axis of the ellipse is calculated in dependence upon the determined standard deviation for a respective measurement.

11. A coin validator including means for taking measurements of a coin, and a control circuit operable

to validate the coin in accordance with a method as claimed in any one of claims 1 to 7.

12. A banknote validator comprising means for taking measurements of a banknote, and a control circuit operable to validate the banknote in accordance with a method as claimed in any one of claims 1 to 7.

13. A coin validator substantially as herein described with reference to the accompanying drawings.

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Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

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Relevant Technical fields

(i) UK Cl (Edition K) G4V (VPN,VPG,VPCB,VPCC,VPCD)
G4X (X6)

(ii) Int Cl (Edition 5) G07D G07F

Search Examiner

LINDA HARDEN

Databases (see over)

(i) UK Patent Office

(ii) WPI

Date of Search

24 OCTOBER 1991

Documents considered relevant following a search in respect of claims 1-13

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
	NONE	

SF2(p)

1tp - c:\wp51\doc99\fil000276

Category	Identity of document and relevant passages	Relevant to claim(s)

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